Dryden Flight Research Center
Edwards, California 93523-0273

DCP-S-024
Revision: A

DRYDEN CENTERWIDE PROCEDURE

CODE SH

NON-IONIZING RADIATION SAFETY

Electronically Approved by:
Associate Director

Approved by:
Director, Safety and Mission Assurance

Approved by:
Chief, Safety, Health, and Environmental Office

DOCUMENT HISTORY PAGE

This page is for informational purposes and does not have to be retained with the document.

DATE APPROVED	ISSUE	PAGE	AMENDMENT DETAILS
2/3/99	Baseline		
See IDMS Document Master List	A	All	Pg. 1 – Fixed footer, modified header, changed Approved by: Acting Director to Director Pg. 3 – Modified page numbers in table of contents. Pg. 3 – Changed form DFRC 223 to DFRC 222 Section 7.1 updated record maintenance Provided links to Dryden documents and forms Corrected formatting errors and grammatical changes

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1.0 INTRODUCTION

1.1 Purpose

This Dryden Centerwide Procedure (DCP-S-024) establishes procedures and documentation requirements which provide safety controls for non-ionizing radiation operations.

1.2 Applicability

DCP-S-024, applies to government and non-government personnel at DFRC and at DFRC controlled off-site operations.

1.3 Scope

DCP-S-024 establishes safety policies and procedures, and defines responsibility for persons working with non-ionizing radiation.

2.0 APPLICABLE DOCUMENTS

2.1 Reference Documents

- NPD 8710.2B, NASA Safety and Health Program Policy, This NPD establishes the requirements for the NASA wide safety and health programs and is the authority for this DCP.

- 29 Code of Federal Regulations (CFR), Part 1910.97, Non-Ionizing Radiation. While this CFR is an authority document it is somewhat limited in specific instructions for developing and maintaining a non-ionizing radiation safety program.

- ANSI Z136.1, for Safe Use of Lasers, and ANSI Z136.2, Safe Use of Optical Fibers Communication Systems Utilizing Laser Diode and LED Sources. DFRC accepts these Standards as authority for establishing the DFRC Laser Safety Program. Reference copies are available in the Safety Office.

- 21 CFR 1040.10 and 1040.11. Specifies manufacturer's requirements for certification of equipment, hazard information, and warning labels. DFRC will purchase and use only non-ionizing radiation equipment meeting the requirements of this CFR.

- National Fire Protection Association 70: National Electrical Code (NEC). This code establishes the majority of safety procedures used in an industrial setting

such as that found at DFRC. It provides specific procedures for nearly every electrical application. Every person working with electrical sources or equipment at DFRC must have access to this document. For interpretations or questions regarding NEC contact the DFRC Safety Office.

- NPD 1441.1 Records Retention Schedules. This document sets forth the minimum retention periods of federal records of NASA.

- Department of Defense(DoD) Document 316-98, Laser Range Safety. This document covers requirements that must be met during open-air laser operations conducted on DoD controlled ranges or test facilities.

- AFOSH Standard 161-10, Health Hazard Control for Laser Operations. This standard includes a guide for operation of lasers from aircraft.

- American Conference of Governmental Industrial Hygienists (ACGIH), Threshold Limit Values for Chemical Substances and Physical Agents and Biological Exposure Indices. This document sets the Threshold Limit Values (TLVs®) and Biological Exposure Indices (BEIs®) for microwaves and RF exposure. See Tables 1 and 2 of this document for TLV® values.

- ANSI/IEEE C95.3, Measurement of Potential Hazardous Electrical-magnetic Fields - RF and Microwave. This document is used as a guideline for DFRC microwave safety.

- ANSI Z535.1, .2, & .3, Environmental and Facility Safety Signs. This series of Standards set requirements for design, color, and criteria for warning signs.

- Underwriters Laboratories UZ746C, Polymeric Materials – Use In Electrical Equipment Evaluation. This document covers requirements for parts made of polymeric materials that are used in electrical equipment and describe the various test procedures and their use in the testing of such parts and equipment.

3.0 ROLES and RESPONSIBILITIES

3.1 Overview

The chain of responsibility for ensuring that there is a safe work environment at DFRC that follows required safety standards, regulations, codes, and guidelines starts with the Center Director and flows downward through management and supervisors. In addition, each person who works at DFRC must understand that a "condition of employment" is to observe all safety specifications applicable to the task being performed.

3.2 Directorates and Single Letter Offices

Are responsible for ensuring that risk assessments of non-ionizing radiation operations within their area of responsibility are made and that appropriate safety measures are followed when non-ionizing radiation operations are conducted.

3.3 Radiation Safety Committee (RSC)

The formation and membership of the RSC is defined in DCP-S-023, Ionizing Radiation. The RSC will meet quarterly when non-ionizing radiation activities are in progress and before any new laser or microwave program is put into operation. Responsibilities of the RSC are:

- ensure that the DFRC non-ionizing radiation program/s are in compliance within current regulations and standards.
- make recommendations to the Chief, Safety, Health, and Environmental Office on items involving the Non-ionizing Radiation Safety Program.

3.4 Safety, Health, and Environmental Office

The Chief, Safety, Health and Environmental Office has safety oversight responsibilities for Non-ionizing Radiation Programs at DFRC and as such will:

- advise management on safety issues concerning non-ionizing radiation safety.
- ensure that non-ionizing radiation programs conducted at DFRC conform to applicable safety regulations and technical guidelines.
- appoint the Laser Safety Officer (LSO).
- investigate non-ionizing radiation incidents and accidents and report findings to management and required agencies.
- review and up-date this DCP annually or more frequently if non-ionizing radiation activity so dictates.

3.5 Laser Safety Officer (LSO)

The LSO is appointed by the Chief, Safety, Health, and Environmental Office and functions as a link between the user, the Radiation Safety Committee, and the

Chief, Safety, Health, and Environmental Office on matters of non-ionizing radiation safety. Duties of the LSO include:

- approval of proposed Authorized Laser Users (ALUs) after a review of the ALU's qualifications.
- advise users concerning precautionary measures required for the safe use of non-ionizing sources.
- provide the services and equipment for monitoring non-ionizing radiation sources.
- conduct inspections and surveys necessary for an evaluation of the Non-ionizing Radiation Safety Program and report findings to the Chief, Safety, Health, and Environmental Office.
- prepare and submit required reports pertaining to non-ionizing radiation operations.
- maintain inventory of non-ionizing radiation systems.
- complete DFRC-220, "Laser Safety Permit," for each laser on site and provide a copy of the permit to the ALU to be posted at the laser site. The LSO must approve initial laser and microwave equipment installation and any movement or reinstallation of such equipment.
- evaluates laser operations proposed by visiting experimenters.

  In the absence of the LSO, the Chief, Safety, Health, and Environmental Office will designate an alternate or act as the LSO.

3.6 Authorized Laser User (ALU).

The ALU is responsible for ensuring compliance with laser safety regulations in the operation of laser equipment. The ALU will:

- ensure every person working with lasers under his/her supervision has availability to a copy of ANSI Z136.1, for Safe Use of Lasers.
- ensure that the laser project is properly authorized and permitted, when required, and that personnel using lasers are properly trained and under direct supervision.

- establish and maintain a current list of those persons authorized to operate Class 2, 3a, 3b, and 4 lasers under direct supervision and will furnish a copy of the list to the LSO.

- maintain a current inventory of lasers under his/her control including the operational location of portable units, and will furnish a copy to the LSO. (see DFRC-223, Non-ionizing Radiation Laser Inventory).

- ensure there is appropriate control of laser hazards, including door interlocks, and warning signs and warning bells where applicable.

- ensure Standard Operating Procedures (SOPs) are submitted and approved for Class 3b & 4 lasers prior to initial operation and reviewed yearly or sooner whenever procedures are amended due to deviation from the standard operating mode

- in the event of an accident involving an injury, send the affected person involved to the Health Unit or have the Health Unit respond and then immediately notify the line supervisor and LSO.

- assure that all persons working on class 3 & 4 laser projects have appropriate laser eye exams.

3.7 Authorized User of Microwave/RF Equipment

The Authorized User of Microwave/RF Equipment is responsible for ensuring compliance with this DCP and ANSI/IEEE C95.3. Other responsibilities include:

- preparing an initial Safety Review document for new projects or modifications of existing microwave/RF facilities.

- giving safety instructions to personnel using microwave/RF equipment under his/her supervision.

- ensuring that appropriate safety controls are in place.

4.0 LASER SAFETY CONTROLS

4.1 Laser Classification.

Lasers are classified by the ability of the primary laser beam or reflected primary laser beam to cause biological damage to the eye or skin during intended use. Multi-wavelength users shall be classified at their highest or most dangerous level of output. For complete explanation of laser

classifications see ANSI Z136.1, for Safe Use of Lasers. In general, the classifications are as follows:

4.1.1 Class 1 Lasers. Are considered to be incapable of producing damaging radiation levels and are, therefore, exempt from any control measures or other forms of surveillance with the exception of applicable requirements for embedded lasers.

4.1.2 Class 2 Lasers. Are low power and divided into two subclasses, 2 and 2a. A Class 2 laser emits in the visible portion of the spectrum (0.4 - 0.7 μm) and eye protection is normally afforded by the aversion response, including the blink reflex.

4.1.3 Class 3 Lasers. Are medium power and divided into two subclasses, 3a and 3b. Class 3 lasers may be hazardous under direct and specular reflection viewing conditions, but the diffuse reflection is not usually a hazard.

4.1.4 Class 4 Lasers. Are high power and a hazard to the eyes and skin from direct beam and to the eyes from diffuse reflection. Class 4 can also be a fire hazard.

4.2 Administrative Controls

4.2.1 Permits. Lasers classified as 3b or 4 must have a DFRC laser permit and an approved Standard Operating Procedure (SOP) in place before they may be operated.

4.2.2 Modification of ANSI Standard. Application of ANSI Z136.1 may be modified for specific laser installations and operations when approved by the LSO. Challenges to LSO decisions will be evaluated by the RSC.

4.2.3 Purchase Requests. All purchase requests for lasers shall be approved by the LSO.

4.2.4 Laser Tracking. Anyone responsible for bringing non-ionizing radiation equipment onto the DFRC site will notify the LSO at the Safety Office and provide the laser type, power, class, manufacture, wavelength, beam type,
beam diameter, beam divergence, model number, serial number and, if possible, the pulse frequency and duration and purpose of the equipment.

4.2.5 Equipment Compliance. Laser equipment purchased or manufactured at DFRC will comply with performance standards of 21 CFR 1040.10 and 1040.11 unless specific exemptions is obtained from the U.S. Department of Health and Human Services, Food and Drug Administration (FDA).

4.3 Worksite Safety Controls

4.3.1 Labels. All lasers must bear a laser hazard classification label. If the manufacture's label is not present and the laser class is unknown, the ALU will consult the LSO to determine the proper classification.

4.3.2 Warning Signs. Laser laboratories and other ground based laser locations must be posted with appropriate warning sign/s. See 4.6 Laser Warning Signs for details.

4.3.3 Laser Operators. Only qualified and authorized persons shall operate lasers or laser systems.

4.3.4 Laser Beam Path. Lasers shall be mounted so that the beam path is not at eye level for standing or seated personnel. Exceptions must be approved by LSO. Personnel shall not look into the primary beam. Specular reflections from the beam shall be avoided.

4.3.5 Beam Termination. Laser beams shall be terminated at the end of their useful path by a material which is non-reflective and fire resistant.

4.3.6 Laser Alignment. Aiming or aligning the laser with the eye by looking along the axis of the beam shall be avoided. Power will be turned down to Class 1 where possible for alignment or the beam path may be traced with a paper card while wearing laser goggles.

4.3.7 Personal Protective Equipment. When the energy output of the laser could damage the eyes or skin, personnel shall wear protective equipment such as laser safety eyewear and clothing. Reflective items such as watches and rings shall be removed.

4.3.8 Secondary Beams. If a secondary beam can emerge from the rear aperture of a laser it shall be covered. Likewise, an unused beam resulting from the use of a beam splitter shall be terminated.

4.3.9 Laser Enclosures. Windows, doorways, and portals of laser laboratories shall be covered to prevent hazardous laser radiation from being transmitted to outside passages.

4.3.10 Non-beam Hazards. Personnel shall take suitable precautions to avoid other types of hazards associated with the use of lasers such as electrical, cryogenic, toxic, or corrosive material. These hazards shall be guarded and controlled.

4.3.11 Ventilation. A specialized local ventilation system will be required at laser targets which produce toxic fumes or gasses, or for Laser Doppler Velocimeter seed material.

4.3.12 Housekeeping. Housekeeping is especially important in laser laboratories. All combustible material, flammable liquids, and reflective materials shall be properly stored. Aisles and exits will be marked and kept clear.

4.3.13 Firing Systems. Laser electronic firing systems shall incorporate a "fail safe" system design so that accidental pulsing of a stored charge is avoided.

4.3.14 Waste Materials. The ALU or designee will notify the Safety, Health, and Environmental Office when it is necessary to dispose of any hazardous chemical waste.

4.4 Outdoor Laser Operation

4.4.1 Nominal Hazard Zone (NHZ)

- The LSO shall effect an analysis to establish the NHZ for outdoor lasers if not available as part of the project documentation or if not furnished by the manufacturer.

- The NHZ shall be clearly posted with laser warning signs and demarcated and identified as a laser hazard area. A combination of physical barriers and screening may be used to isolate the NHZ. Personal protective equipment may be required by persons within the NHZ.

- Only authorized personnel shall operate outdoor laser equipment or be allowed in the NHZ.

4.4.2 Beam Path. The laser beam path shall not be maintained at or near eye level without specific authorization from the LSO. The beam will be confined and terminated whenever possible. Directing the beam toward vehicles, manned structures, or aircraft, shall be prohibited unless proper

clearance is obtained and adequate training and protective equipment is provided and used by all personnel within the target area.

4.4.3 Laser Isolation. When outdoor laser equipment is not in use it shall be disabled in a manner that prevents unauthorized use. A lock-out device or the removal of an electrical source fuse meets this requirement.

4.4.4 Atmospheric Hazards. The operation of Class 3b or 4 lasers or laser systems during rain, snowfall, fog, or dusty atmospheres may produce hazardous reflections near the beam. In such conditions the LSO shall evaluate the conditions, terminate operations, or specify the use of appropriate PPE.

4.4.5 DoD Document 316-98, Laser Range Safety. When doing laser operations where the laser beam has the potential of striking an orbiting craft, the Program Manager or LSO shall contact the Laser Safety Clearing House to obtain a "Site Window" clearance. This clearance may be obtained from the Orbital Safety Officer, U.S. Space Command, J3SOO, 1 NORAD Road, Suite 9-101, Cheyenne Mountain AFB CO 80914, Stop 4.

4.5 Aircraft Laser Operations (Class 3b & 4 lasers)

4.5.1 Program Identification. Programs at DFRC that propose to use airborne lasers will be identified early in the system development phase in order to allow time for the Program Manager, RSC, and LSO to review safety requirements and resolve compliance issues.

4.5.2 Laser Interlocks. Airborne laser systems will have interlocks to prevent inadvertent output. Override capability, protected from inadvertent operation, will be available for ground operations and maintenance service.

4.5.3 Laser Safe Range. The aircraft commander has the responsibility of ensuring the laser is used in accordance with the mission profile and in no case will allow the laser to be operated outside its safe range.

4.5.4 Nominal Hazard Zone. For long distance airborne laser shots the NHZ shall be as large as practical. A buffer zone should be added to the NHZ for protection of persons outside the NHZ. AFOSH Standard 161-10 includes a guide for operation of lasers from aircraft. Special care must be taken if there is a potential of the laser beam striking an orbiting craft. See 4.4.5, DoD Document 316-98 for further information.

4.5.5 Hazard Analysis. A written preflight hazard analysis will be prepared by a qualified person/s for each airborne laser operation. The hazard analysis will be reviewed by the LSO assigned to the mission and at a minimum will include the following:

- potential catastrophic events and procedures for high-speed laser shut down.
- special hazards associated with the laser operation and mission profile, and control measures to meet these hazards to include safety for crew members, the aircraft, and the public at large.
- other factors such as atmospheric effects of beam propagation, transmission through intervening materials, the use of optical viewing aids, electrical hazards, use of cryogenic materials, toxic vapors, etc.

4.6 Laser Warning Signs

4.6.1 Warning Signs. The requirements for laser warning signs are given in ANSI Z136.1 and ANSI Z535.1, .2, & .3. Signs may be obtained from the LSO.

4.6.2 Displaying Signs. Warning signs shall be displayed near the laser operation and in a location where they may best be seen.

4.7 Modification of Laser Systems

The LSO shall review and approve proposed modifications to permitted lasers where such modifications could affect output power or operating characteristic and make the laser potentially more hazardous. The LSO shall ascertain what class the laser will be assigned and what changes are required in control measures.

4.8 Medical Surveillance

Laser personnel both, government and non-government, who work with Class 3b and 4 lasers or who are permitted by an ALU to be in designated laser control areas must receive a thorough ophthalmologic examination before the laser work begins. Incidental personnel, (those persons who are unlikely to be exposed to damaging laser energy but are associated with the laser program and who, at times, may be near laser operations) shall be given a visual acuity exam. The ALU will arrange with the Health Unit for the examinations. Follow-up exams will be required as follows:

- immediately after a confirmed or suspected accident has occurred involving an actual or suspected eye injury.

- a follow-up examination is required at the conclusion of the person's employment or when there is no expectation that the employee will again be exposed to laser radiation.

4.9 Personal Protective Equipment

4.9.1 Eye Protection. Appropriate protective eyewear shall be available for use whenever personnel could be exposed to levels of laser radiation above the Maximum Permissible Exposure (MPE) established in the ANSI Z136.1 Standard. In multi-wavelength operations alternate controls may be necessary. The LSO will ensure that:

- laser eyewear is clearly labeled with the optical density values and the useful wavelengths.

- eyewear is periodically inspected to ensure serviceability.

- an annual inventory of eyewear is submitted to the LSO by ALUs.

4.9.2 Skin Protection. Protective gloves, clothing, and shields will be used to prevent exposure of the skin when levels of laser radiation are above the MPEs for skin as established by ANSI Z136.1 Standard.

4.10 Associated Hazards (Non-Beam Hazards)

4.10.1 Laser Generated Air Contaminants (LGAC). Three major control measures are used to reduce LGAC hazards. They are; exhaust ventilation, isolation of the process, and respiratory protection . Hazards that LGAC may pose are:

- vaporized target materials from high-energy laser cutting, drilling, and welding operations which may be toxic or explosive.

- gases which flow through laser systems or by-products of laser reactions such as bromine, chlorine, fluorine and hydrogen cyanide. These gases can be extremely toxic or explosive.

- gases or vapors from cryogenic coolants may cause cold burns, asphyxiation, or become an explosive hazard.

4.10.2 Explosions

High pressure arc lamps, filament lamps, and capacitor banks in laser equipment shall be enclosed in housings which can withstand the maximum explosion pressures resulting from lamp disintegration. The laser target and elements of the optical train which may shatter during laser operation shall also be enclosed or equivalently protected to prevent injury to operators and observers. Components such as electrolytic capacitors may explode if subjected to voltages higher than their ratings with the result that ejected metal may bridge live electrical parts. Such capacitors shall be tested to make certain that they can withstand the highest probable potentials should other circuit components fail, unless the capacitors are adequately contained so as not to create a hazard.

4.10.3 Radiation (non-beam)

1. X-rays. X-rays generated by high voltage (over 15 KV) power supply tubes shall be identified and the information provided to the LSO.

2. Ultraviolet Radiation. Emitted from laser discharge tubes and pumping lamps shall be suitably shielded so that personnel exposures are maintained within the TLV® specified by the American Conference of Governmental Industrial Hygienists (ACGIH).

4.10.4 Electrical

Several electrocutions have occurred to individuals troubleshooting or servicing laser equipment. In general, the individual was working alone or other personnel working nearby did not know how to administer Cardiopulmonary Resuscitation (CPR). The importance of adequate training, and the use of the "buddy system" when working around high voltage laser power supplies cannot be over stressed.

Protective electrical circuit design is also important. The laser resonator and electro-optical elements shall be designed so that no exposed metallic element is above ground potential. Other electrical safety factors include the following:

1. Installation: laser equipment shall meet the electrical safety requirements of NFPA 70, (NEC). The intended application of the laser equipment determines the method of electrical installation and

connection to the power supply circuit (for example, conduit vs. flexible cord).

2. Shock: live parts of circuits and components with peak open-circuit potentials over 50 volts are considered hazardous. Such circuits require positive protection against contact. For equipment intended for general use, interlock switches (and capacitor bleeder resistors, if applicable) or their equivalent shall be installed to remove the voltage from accessible live parts to permit servicing. Bleeder resistors shall be of such size and rating as to carry the capacitor discharge current without burnout or mechanical injury. Circuits and components with peak open-circuit potentials of 2500 volts or more shall be adequately covered or enclosed if an appreciable capacitance is associated with the circuits.

   If servicing of equipment requires entrance into an interlocked enclosure within 24 hours of the presence of high voltage within the unit, a solid metal grounding rod shall be utilized to ensure discharge of high-voltage capacitors. The grounding rod shall be firmly attached to ground prior to contact with the potentially live point. A resistor ground rod (for example, a large-wattage ceramic resistor) may be used prior to application of the previously mentioned solid conductor grounding rod to protect circuit components from overly rapid discharge, but shall not be used as a replacement.

3. Ground: the frames, enclosures, and other accessible non-current-carrying metallic parts of laser equipment shall be grounded. Grounding shall be accomplished by providing a reliable, continuous metallic connection between the parts to be grounded and the grounding conductor of the power wiring system.

4. Electrical Fire: components in electrical circuits shall be evaluated with respect to fire hazards. Enclosure, barriers or baffles of non-metallic material shall comply with "Polymeric Materials for use in Electric Equipment," Underwriters Laboratories Standard, UL746C.

5. Markings: the user shall ensure that each laser is permanently marked with its primary electrical rating in volts, frequency, and watts or amperes.

4.11 Flammability of Laser Beam Enclosures.

Enclosure of Class 4 laser beams can result in potential fire hazards if enclosure materials are exposed to irradiances exceeding 10 W/cm^2 for total beam powers exceeding 0.5 W. Plastics and paper products are excluded, but their use at DFRC is not recommended unless program essential.

4.12 Liquid Cryogenic Coolants

In liquid form, these coolants may cause tissue damage if splashed in the eyes or into the shoes. Personal protective equipment must be worn when handling this material.

4.13 Laser Dyes

Certain laser dyes are highly toxic or carcinogenic. Care must be taken when handling and preparing dye solutions, and during operations where dye lasers are in use. A MSDS for dye compounds must be available to laser personnel.

4.14 Noise

Noise from certain lasers, such as excimer lasers, may be of such intensity that noise control is necessary.

4.15 Hazardous Waste Disposal

Contact the Safety, Health, and Environmental Office for hazardous waste pick-up.

4.16 Working Space

The ALU will ensure sufficient room for personnel to work and maneuver freely during laser operations.

4.17 Ergonomics

Some laser operations require repetitive hand, wrist, and arm movements which could cause medical problems. The ALU shall be aware of these problems and shall become familiar with proper ergonomic solutions.

5.0 MICROWAVE/RF RADIATION SAFETY CONTROLS

5.1 Reference

ANSI/IEEE C95.3, Measurement of Potential Hazardous Electrical-magnetic Fields - RF and Microwave, covers the safety application of the frequency range from 30 kHz to 300 GHz and is applicable to both total and partial body irradiation.

5.2 Warning Signs

Warning signs for RF and Microwave hazards must be posted on the access panels of irradiated enclosures of equipment and on entrances to areas where exposures exceed the limits specified in ANSI/IEEE C95.3; Measurement of Potential Hazardous Electrical-magnetic Fields-RF and Microwave.

5.2.1 Hazardous Notice Door Signs. Are required on:

- equipment that could create 60Hz electric fields above 2.5 kV/m and does not have electric field shielding.
- permanently installed RF equipment capable of radiating over 1 W into an open area at frequencies between 3 kHz and 300 GHz or emitting 100 W if output is completely enclosed by coaxial cables, waveguides, or dummy or real loads.
- satellites and permanently installed communications transmitters.
- portable radios (transmitters) over 7 W. (some frequencies may be exempt, check with LSO).
- induction heaters.
- main power-supply rooms of buildings.

5.3 Exposure Limits.

TLVs® refer to radiofrequency (RF) and microwave radiation in the frequency range 30 kHz to 300 GHz and represent conditions under which it is believed that nearly all workers may be repeatedly exposed without adverse health effects. The TLV®s, in terms of Root Mean Square (RMS) electric (E) and magnetic (H) field strengths, the equivalent plane-wave free-space power densities (PD), and induced currents in the body which can be associated with exposure to such fields or

contact with objects exposed to such fields, are given in Table 1 and Figure 1 as a function of frequency, f, in MHz. Access should be restricted to limit the RMS RF body current and potential for RF shock or burn as given in Table 2.

For freestanding individuals (no contact with metallic objects), RF current induced in the human body, as measured through each foot, should not exceed the following ceiling values:

$I = 1000f$ mA for $(0.03 < f < 0.1$ MHz)
$I = 100$ mA for $(0.1 < f < 100$ Mhz)
mA = milliampere

Table 1
Radiofrequency/Microwave Threshold Limit Values

Electromagnetic Fields f=frequency in MHz				
		Electric	Magnetic	Averaging
Frequency	Power Density, S (mW/cm^2)	Field Strength,E (V/m)	Field Strength,H (A/m)	Time E^2, H^2 or S (minutes)
30 kHz -100kHz		614	163	6
100 kHz - 3 MHz		614	16.3/f	6
3 MHz - 30 MHz		1842/f	16.3/f	6
30 MHz - 100 MHz		61.4	16.3/f	6
100 MHz - 300 MHz	1	61.4	0.163	6
300 MHz - 3 GHz	f/300			6
3 GHz - 15 GHz	10			6
15 GHz - 300 GHz	10			$616{,}000/f^{1.2}$

The exposure values in terms of electric and magnetic field strengths are the values obtained by spatially averaging values over an area equivalent to the vertical cross-section of the human body, (projected area).

Table 2
Induced and Contact Radio Frequency Currents
Maximum Current (mA)

Frequency	Through Both Feet	Through Each Foot	Contact
30 kHz - 100 kHz	2000f	1000f	1000f
100 kHz - 100 MHz	200	100	100

It should be noted that the current limits given above may not adequately protect against startle reactions and burns caused by transient discharges when contacting and energized object.

5.4 Measurements.

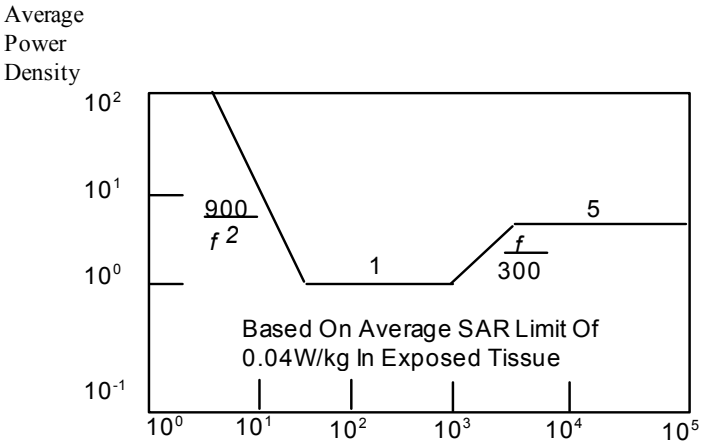
For both pulsed and non-pulsed fields, the power density, the squares of the field strengths, and values of specific absorption rates (SARs) or input power as applicable, are averaged over any 0.1 hr period.

Measurements to determine adherence to the recommended protection guides shall be made at distances 5 cm. or greater from any object (refer to ANSI/IEEE C95.3.)

Figure 1

Radio Frequency Protection Guide for
Whole-Body Exposure of Human Beings

Note: f = frequency
Frequency (Mhz)



5.5 Microwave/RF Project Safety Review

Prior to installing new microwave/RF equipment or modifying existing equipment, a Project Safety Review document must be submitted by the Authorized User to the LSO for review. The document shall include:

- a description of the system and its application.
- a diagram showing the beam path.
- operating Parameters:
  frequency
  power output
  pulse description
  antenna gain
  antenna dimension
  antenna type
  polarization of transmitted wave
- Standard Operating Procedure (SOP) designed to minimize hazards to personnel.
- microwave/RF projects shall be reviewed by the LSO prior to initial operation and on an annual basis or when the researcher's project deviates from approved Standard Operating Procedures.

5.6 Operational Microwave/RF Safety

The following safety precautions and procedures must be taken when working near microwave/RF equipment:

- Standard Operating Procedures (SOPs) must be posted near all operational equipment. The SOP will outline radiation protection procedures for the equipment in use. The SOP will be reviewed and approved by the LSO.
- only individuals who have been instructed in the potential hazards of microwave/RF radiation and in safe procedures will be permitted to work in the vicinity of the equipment.
- microwave/RF warning signs must be posted.
- personnel must be restricted from the area immediately in front of any radiating antenna.
- transmissions with un-terminated wave guide must be avoided.

- free space transmission within buildings must be avoided. During those test procedures where such transmissions are required, make certain that personnel are not being exposed to the radiated beam.

6.0 TRAINING

Training shall be provided to all employees working with or around lasers Class 3b and 4. Orientation training shall be given to persons working with or around lasers Class 2 or 3a. Training is good for three (3) years.

6.1 Training Topics for Class 3b & 4. Training shall include the following:

- fundamentals of laser operation, (physical principles, construction, etc.)
- bioeffects of laser radiation on the eyes and skin.
- relations of specular and diffuse reflections.
- non-radiation hazards of lasers (electrical, chemical, reaction by-products, etc.).
- ionizing radiation hazards (x-rays from power sources and target interactions).
- laser and laser system classifications.
- control measures. (Engineering Procedures, Inspections, & PPE).
- overall management and employee responsibilities.
- medical surveillance practices.
- CPR for personnel servicing or working on lasers of high voltages or those capable of producing high (lethal) voltages.

6.2 Training for Class 2 and 3a laser users.

- explanation of DFRC laser operations.
- compare difference of laser light to normal light.
- explain classes of lasers and hazards they represent.

- explain the do's and don'ts of laser operations.

7.0 RECORDS

7.1 Record Maintenance

7.1.1 Authorized Laser User

The Authorized Laser User will keep records such as orders, personnel exposure levels receipts and, inventories. After completion of the project a disposition for the records will be made. NPD 1441.1; Records Retention Schedules, will be used for disposition of the records.

7.1.2 Radiation Safety Officer

The RSO is responsible for maintaining a copy of records and receipts such as approval requests and authorizations, procurement, inventories, surveys, calibrations, and any other records that pertain to laser operations.

8.0 NON-IONIZING RADIATION SAFETY FORMS

Example Only
LASER SAFETY PERMIT

<table>
<tr><td>Permit Number: _____</td><td>Issue Date: _____</td><td>Expiration Date_____
Class of Laser: _____</td></tr>
<tr><td>Location: (Building, Aircraft, or Site):</td><td>Drawing and Procedure No.</td><td>Laser Type : _____</td></tr>
<tr><td>Activities Requiring Approvals, i.e., Facilities, Equip., etc.</td><td>Manufacture:</td><td>Power:</td></tr>
<tr><td>Activity Approved Subject to Following Conditions:</td><td>Beam Wavelength: _____
Pulse Frequency: _____</td><td>Beam Type: _____
Pulse Duration: _____</td></tr>
<tr><td>Persons Authorized to Operate Laser System Under This Permit:
1. 5.
2. 6.
3. 7.
4. 8.</td><td>Beam Diameter: _____
Model No. _____</td><td>Beam Divergence: _____
Serial No. _____</td></tr>
<tr><td>Review Authority Action</td><td colspan="2">Activity Completed</td></tr>
<tr><td></td><td colspan="2"></td></tr>
<tr><td></td><td colspan="2"></td></tr>
<tr><td>Approval: Date Signed
Chief, Safety, Health, and Environmental Office</td><td colspan="2">Approval: Date Signed
Laser Safety Officer</td></tr>
<tr><td>Instructions:
1. A copy of this permit must be posted in a conspicuous place at the location described prior to laser operations.

2. Submit a request for a new permit at least 30 days prior to the expiration date if:
a. The activity will not be completed by the expiration date;
b. Any changes are made in the conditions as described in the permit.</td><td colspan="2">3. When the activity is completed, remove this permit, indicate the completion date and return it to the Laser Safety Officer.

4. For questions concerning this permit or laser operations contact the Laser Safety Office at the Safety Office.</td></tr>
</table>

LASER USER EXPERIENCE RECORD

NAME _____ ORG CODE _____

I. TRAINING

1. Degree or Related Courses	2. Where Trained	3. Duration of Training	4. On-The-Job Training	5. Formal Course
			☐ Yes ☐ No	☐ Yes ☐ No
6. Laser Courses			☐ Yes ☐ No	☐ Yes ☐ No
7. Laser Safety Course			☐ Yes ☐ No	☐ Yes ☐ No

II LASER EXPERIENCE

TYPE OF LASER	POWER	USE (CHEMICAL ANALYSES DISTANCE MEASURING, ETC.)	DURATION OF EXPERIENCE
8.			

Code. 1. Engineering, Physics, Biology, etc.
2. University, school, etc.
3. Duration of Training.
6. List laser training courses and dates.
7. List laser safety courses and dates.
8. List laser type, power, use and experience

III RECEIPT OF REGULATIONS

I have read and understand the following material:

☐ DCP-S-024: Non-ionizing Radiation Safety

☐ American National Standards Institute (ANSI) Z136.1, for Safe Use of Lasers

_____ _____
Signature Date

DFRC-221
Jan 1999

NON-IONIZING RADIATION LASER INVENTORY

AUTHORIZED LASER USER_____ ORG. _____

BLDG. _____ ROOM NO. _____TELE. _____

LASER DESCRIPTION:

1. CLASS AND TYPE _____/_____
2. MANUFACTURER _____
3. MODEL NO. _____
4. SERIAL NO. _____
5. DFRC PROPERTY NO. _____
6. WAVE LENGTH EMITTED _____
7. MAXIMUM OUTPUT _____
8. BEAM TYPE _____
9. PULSE FREQUENCY_____
10. PULSE DURATION_____
11. BEAM DIAMETER_____
12. BEAM DIVERGENCE_____
13. DFRC PERMIT NO. _____ PERMIT DATE _____

LASER LOCATION:

☐ STATIONARY

BLDG. _____ ROOM NO. _____

NOTE: Stationary lasers will not be moved or stored without the approval of the LSO.

☐ ON AIRCRAFT

TYPE AIRCRAFT _____ TAIL NUMBER _____

☐ PORTABLE/MOBILE

PRIMARY LOCATION

BLDG. _____ ROOM NO. _____

_____ _____
SIGNATURE: AUTHORIZED LASER USER DATE

_____ _____
SIGNATURE: LASER SAFETY OFFICER DATE

DFRC-222
May 2001